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The Metals Price Boom of 1987-89

The Role of Supply Disruptions and Stock Changes

Boum-Jong Choe

Supply disruptions and low stocks, both transitory in nature, had a strong impact on the boom in metals prices in 1987-89, as did the growth of OECD industrial production and depreciation in the U.S. dollar.

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This paper — a product of the International Trade Division, International Economics Department — is part of a larger effort in PRE to understand the short- and long-run behavior of primary commodity prices and the implications of movements in these prices for the developing countries. Copies are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Sarah Lipscomb, room S7-062, extension 33718 (21 pages).

The markets for base metals have changed remarkably in the last few years. A long period of extremely low prices was followed by a sustained price boom in 1987-89 — which continued into 1990 for copper, nickel, lead, and zinc.

What caused the price increases and what they portend for the future are critically important for developing countries heavily dependent on exports of those commodities.

Choe examines the causes of the price boom in terms of market fundamentals. Because of the apparent importance of supply disturbances and low stocks, he developed a semistructural price equation to incorporate supply-side variables. The resulting estimates fit better and explain more than those in earlier studies. Estimation and simulation results suggest that:

• The growth of OECD industrial production was the most consistently important factor in the higher metals prices. This positive factor was largely offset by expected increases in metals production. Much of the boom was attributable to such transitory factors as changes in the exchange rate, supply shocks, and low stocks.

• Depreciation of the U.S. dollar was the dominant contributor to the price increases in the earlier part of the boom — particularly for nickel, lead, and zinc. Changes in interest rates were relatively unimportant.

• Supply disturbances and low stocks significantly increased prices, particularly in 1988. Low stocks have been a more important, consistent factor than supply disruptions.

• Market fundamentals explain most of the price boom but a substantial component remains unexplained, suggesting that excessive speculation ("bubbles") may have contributed to the price increases, particularly for nickel in 1988.

The Metals Price Boom of 1987-89:
The Role of Supply Disruptions and Stock Changes

by
Boum-Jong Choe

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I. INTRODUCTION

The last few years have seen remarkable changes in the markets for base metals. A long period of extremely low prices and pervasive demand pessimism has been followed by strong demand growth and sharply higher prices. Most base metals enjoyed a sustained price boom over the 1987-89 period; the boom has continued into 1990 for copper, nickel, lead, and zinc. The causes of these changes and what they portend for the future are critically important for a number of developing countries heavily dependent on exports of these commodities.

Although much has been reported about the price increases, there has not been a systematic analysis of the various causes and their relative importance. The main purpose of this paper is to evaluate quantitatively the impact of the market fundamentals that contributed to the price boom. An interesting question is whether the residual unexplained by the market fundamentals is large and systematic enough to give credence to the presence of excessive speculation or a "bubble" in the price boom, as often alluded to by market analysts at times of major price increases.

The quantitative evaluation of market fundamentals is based on an extension of the reduced-form price equation model estimated by Gilbert (1986). The extension involves an explicit account of supply disturbances and low stocks along the approach taken by Trivedi (1990). A model similar to that used by Gilbert and Palaskas (1989) is used to estimate supply innovations. The price equation is derived from an explicit model of demand, supply and inventory holding under the assumption of rational expectations; however, since only the price equation is estimated, the rational expectations constraints on the parameters cannot be imposed. Thus, the model is consistent with most other alternative expectations hypotheses.

In the next section, we first review the metals market developments during 1987-89. Initially, Gilbert's model is used in section III to analyze the contribution to the price boom of the market fundamentals included in his model. Section IV presents an extension of Gilbert's model and the results of estimation; the model is then used to simulate the 1987-89 period. The last section concludes the paper.

II. THE METALS PRICE BOOM OF 1987-89

The period 1987-89 was remarkable for the metals markets in several respects. Rarely before have metals prices been sustained at high levels for such an extended period. It is also remarkable in that the price increases followed a long period of extremely low prices and widespread pessimism about the markets' future. Furthermore, in a significant departure from the historical pattern, high metals prices were achieved during a period of relatively modest economic growth.

Chart 1 shows the World Bank's index of base metal prices in nominal and constant dollar terms. Chart 2 shows the nominal price movements for the individual metals. The World Bank's nominal price index for the base metals increased steadily between 1986 and 1989; the index reached a peak during the first quarter of 1989 at a level more than 80% higher than in 1986. The index started to retreat from the second quarter of 1989, but picked up again during the third quarter, because of increases in copper, tin, zinc and lead prices. Between 1986 and the first quarter of 1989, nickel prices increased by 359%, copper prices by 137%, and zinc prices by 149%. Aluminum prices peaked during the second quarter of 1988, at a level 163% higher than in 1986, while tin prices were 64% higher during the second quarter of 1989 than in 1986. Aluminum and tin prices subsequently collapsed mainly due to increased supplies. An all-time high for lead prices was reached during March 1990; nickel, zinc, lead, and copper prices remained at high levels through mid-1990.

It should be noted that the earlier phase of the metals price boom coincides with the period of substantial depreciation of the US dollar, implying that the increases were smaller in terms of the currencies of other major industrial economies. For example, the World Bank's metals and minerals price index in US dollars increased 46% between 1985 and 1988 but declined 22% in terms of the Japanese yen.

In broad and general terms, the price increases can be related to the changes in market supplies and demand. Table 1 summarizes the production, consumption and stock data for the 1980s. Compared with the first half of the 1980s, the most striking change occurred in the demand for metals. Metals consumption growth in the market-economy countries remained in the doldrums during the 1980-85 period, giving rise to highly pessimistic assessments of the metals-mining industry.[1] From 1986 onwards, however, metals consumption started to show a clear departure from the earlier

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[1] Actually, the slowdown of the metals consumption growth rate in the market economies started earlier, from the mid-1970s. The declines in metals consumption per unit of GDP in the major industrial countries over the 1974-1985 period prompted the "structural change" hypothesis. This hypothesis suggested that the low consumption growth rates were symptomatic of fundamental and irreversible declines in the metals intensity of output, presumably due to substitution away from metals, changes in the output mix into less metal-intensive products, and technological innovations.

CHART 1: METALS/MINERALS PRICE INDICES

(1979-81=100)

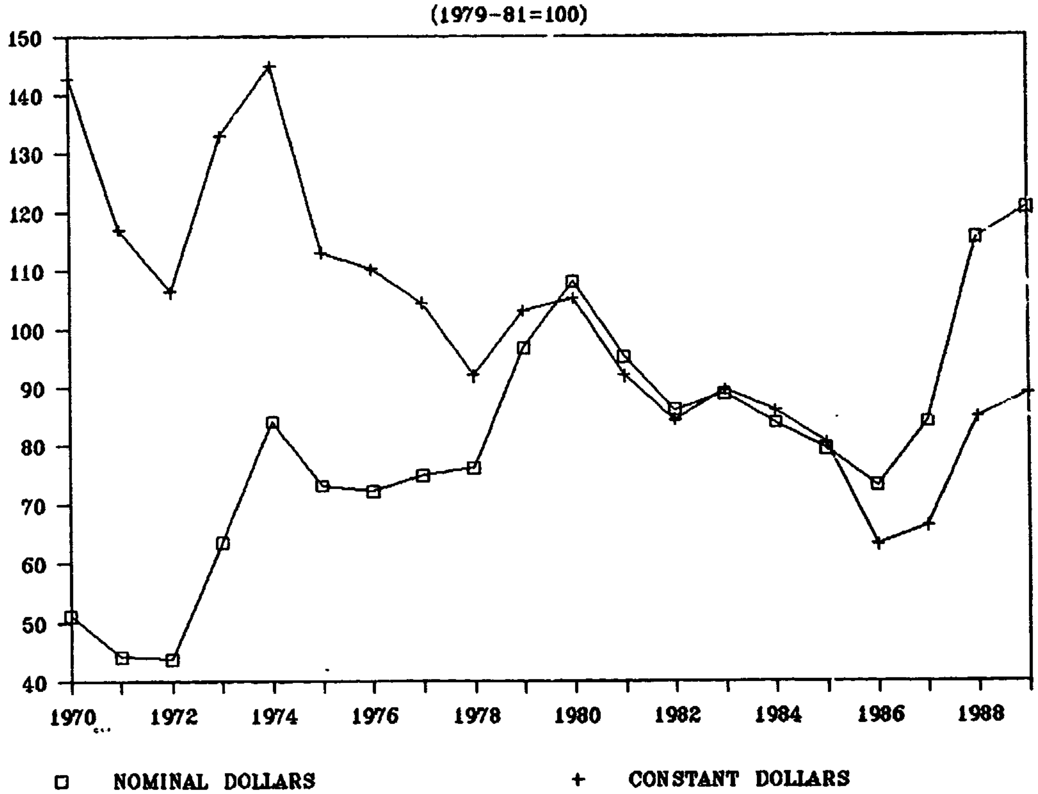

CHART 2: NOMINAL METALS PRICES

(US$/MT OR USC/KG)

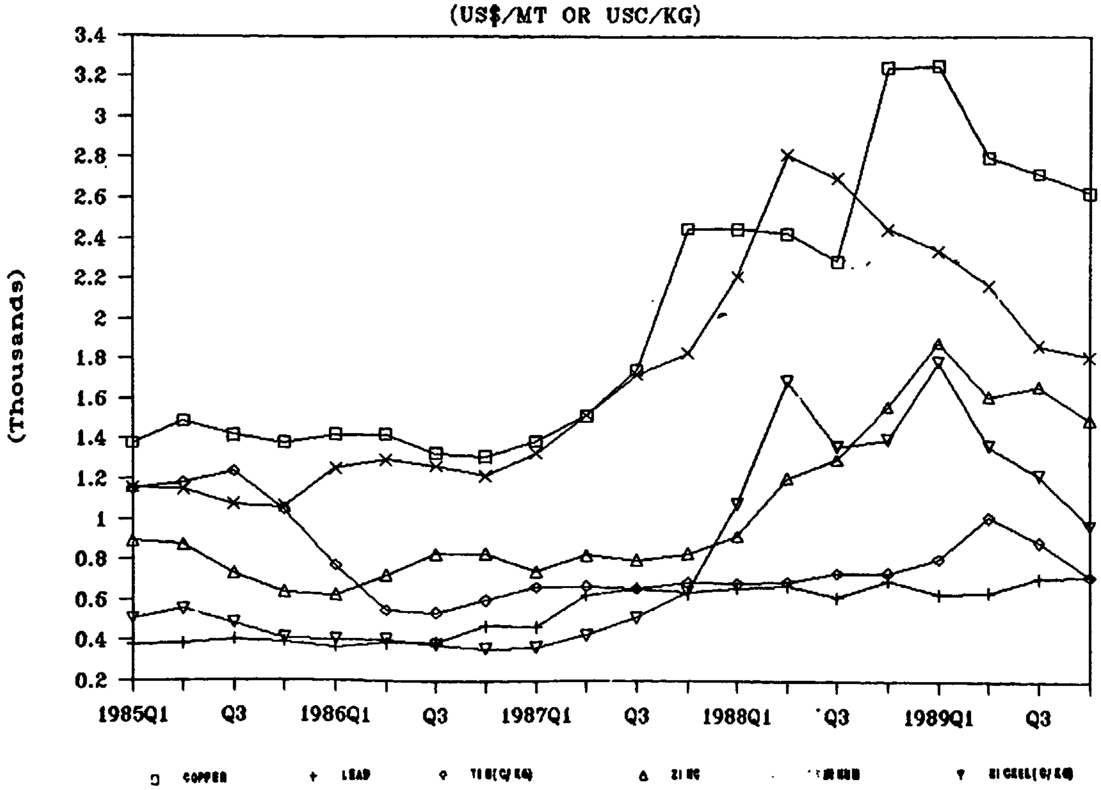

Table 1: World Production, Consumption and Stocks of Base Metals

(Tin and Nickel in '00,000 MT; others in million MT)

	1980	1982	1984	1986	1987	1988	1989
Copper							
Production	9.25	9.42	9.56	9.88	10.21	10.57	11.00
Consumption	9.39	9.04	9.94	10.08	10.44	10.63	10.74
Stocks	1.03	1.64	1.20	0.89	0.52	0.56	0.65
Aluminum							
Production	16.06	13.94	15.94	15.53	16.27	17.32	17.85
Consumption	15.29	14.23	15.57	16.04	16.99	17.74	17.50
Stocks	2.08	3.19	2.78	1.97	1.48	1.62	1.83
Tin							
Production	2.32	2.16	2.25	2.04	2.03	2.23	2.27
Consumption	2.13	1.93	2.22	2.23	2.30	2.35	2.39
Stocks	0.39	0.47	0.50	0.80	0.61	0.50	0.56
Nickel							
Production	7.50	6.23	7.37	7.53	7.93	8.38	8.67
Consumption	7.11	6.53	7.82	7.78	8.37	8.74	8.27
Stocks	2.04	2.02	1.47	1.23	0.89	0.83	0.94
Lead							
Production	5.40	5.23	5.45	5.48	5.67	5.77	5.78
Consumption	5.41	5.25	5.50	5.51	5.61	5.67	5.70
Stocks	0.53	0.56	0.43	0.40	0.44	0.44	0.37
Zinc							
Production	6.17	5.98	6.65	6.80	7.05	7.25	7.39
Consumption	6.18	5.97	6.45	6.70	6.92	7.16	7.11
Stocks	0.79	0.80	0.63	0.62	0.57	0.52	0.55

Note: Stocks are year-end commercial stocks only. Tin commercial stocks are estimated from total tin stocks and the buffer stocks held by the International Tin Council.
Source: World Bureau of Metal Statistics; International Lead and Zinc Study Group.

trends. Consumption growth rates during the 1986-89 period significantly exceeded GNP growth rates and the metals intensity of GDP started to increase in the major industrial economies. Table 2 shows, for the G-7 industrial countries, the growth rates of GNP, industrial production (IP), and metals consumption. It has been suggested that a vigorous expansion of investment and production of metals-intensive capital goods has been the main driving force behind the metals demand growth since 1987. Contrary to the first

Table 2: Growth Rates of GDP, Industrial Production and Metals Consumption of G-7 Countries

(percent per annum)

	GDP (1)	IP (2)	MQ (3)	MQ/GDP (3-1)	MQ/IP (3-2)
1981	1.81	0.56	-3.04	-4.85	-3.60
1982	-0.78	-0.49	-6.84	-6.06	-6.35
1983	3.03	3.80	6.59	3.56	2.79
1984	5.34	8.10	6.79	1.45	-1.31
1985	3.41	2.67	-2.55	-5.96	-5.22
1986	2.70	1.10	0.80	-1.90	-0.30
1987	3.60	3.26	4.72	1.12	1.46
1988	4.51	6.01	5.06	0.55	-0.95
1989	3.42	3.42	-0.04	-3.46	-3.46

Note: MQ is the rate of change of the Divisia index of base metals consumption.
Source: OECD; and International Economics Department, World Bank.

half of the 1980s, the industrial sector growth during 1988-89 exceeded that of the economy as a whole. When metals consumption per unit of GDP or per unit of industrial production (metals intensity) is computed for these countries, we observe that increases and declines are less pronounced in terms of industrial production than in terms of GDP. The metals intensity of industrial production has not shown a significant increase during the 1987-89 period. In other words, much of the increase in metals consumption in 1988 and 1989 is explained by the expansion in industrial production relative to GNP. It is believed that low energy prices and the large pent-up demand for investment were the important factors behind the robust investment activities in the second half of the 1980s.

Events on the supply side made a significant contribution to the price rise in two important ways -- through a reluctance to reactivate idled capacities, and supply disruptions. Recent estimates indicate that the percentage production increases in 1987 and 1988 were substantial, but were less than expected capacity increases. In 1988, for example, the market economies' copper mine capacity increased by more than 200,000 tons, but actual mine production slightly declined. Short-term supply responses to the higher prices have been hardly noticeable in many developing countries. An exception may be tin, which experienced sharp production increases in 1988 when prices started to rise, much of it through reactivation of idled capacities. For other metals, however, most of the production increases originated from new additions to capacity that had been in the pipeline for some time.

During the period of low prices, rationalization and restructuring led to a large reduction of production capacity; the adjustment process was more or less completed by 1986. When the prices increased, most of the idled capacity was not reactivated because of high start-up costs and the widespread expectation that the high prices would not last very long.

In the last several years, the metals-mining industry has been beset by unusually frequent and large supply disruptions of various kinds. It is most unfortunate that many of the developing countries were unable to take full advantage of the high metals prices because of labor disputes, political and social unrest, natural and man-made disasters, and lack of efficient management. Hardest hit were Peru (copper, lead and zinc), Papua New Guinea, and Zambia (copper). Supply problems of less severity also took place in Mexico (copper), Canada (copper, nickel, lead and zinc), Chile and Zaire (copper). These disruptions probably more than wiped out the gains in production through enhanced capacity utilization which occurred mostly in the industrial countries, such as the United States.

III. GILBERT'S INDEX MODEL

As a preliminary, we employ in this section Gilbert's (1986) market-fundamentals model of the metals price index to explain the metals price boom of 1987-89. Gilbert estimated a quarterly model of the World Bank's commodity price indices, one of which is the metals and minerals index shown in Chart 1. Under the assumption that metals markets are efficient, Gilbert derives a reduced-form equation for commodity prices wherein exchange rate changes and developing country debt play a key role. The estimated model expresses changes in the logarithm of the metals and minerals price index in nominal US dollars as a function of its own lagged values and changes in the interest rate, inflation index, OECD industrial production, oil prices, exchange rates, and the debt service of developing countries. Since this is a short-term model, supplies of commodities are assumed to be constant and therefore do not appear in the equation.

Gilbert's index model for metals and minerals is used to simulate the 1987-89 period. Simulation starts from the fourth quarter of 1986. Table 3 attributes the changes in the metals index to the various market fundamentals using the simulation results. It is seen that Gilbert's model overestimates the actual index for 1987 and underestimates for 1988 and 1989; the forecast error widens as time passes, to as much as 14.3% of the actual level of the index for the final quarter of 1989. The lagged effect of changes in the exogenous variables that took place before the fourth quarter of 1986 is shown to be large initially in 1987 but quickly vanishes subsequently. One reason for the overestimation for 1987 could be the model's inability to take account of the relatively large stocks carried over from the preceding year, while the underestimation for 1988-89 could be attributed to the failure to account for the supply disruptions discussed in the previous section.

Table 3: Decomposition of Price Boom with Gilbert's Model

(percent change from 1986 fourth quarter)

	1987	1988	1989
Industrial Production	3.1	13.0	17.7
Exchange Rate	7.3	17.3	11.8
Interest Rate	-0.5	-0.5	-0.4
Oil Price	0.0	1.2	3.0
Interaction Effect*	0.3	-1.8	-2.1
Lagged Effect	20.2	11.3	5.4
Total Explained	29.8	40.5	35.4
Unexplained Residual	-13.4	19.4	31.7
Actual Change	16.4	59.9	67.1

* Interaction effect arises due to the simultaneity between the market fundamentals included in the model.
Source: International Economics Department, World Bank.

Industrial production and exchange rate changes appear to have been the most significant factors that contributed to the metals price boom. The US dollar depreciated against other major currencies through much of the 1986-1988 period, only to turn around and appreciate mildly from mid-1988. Gilbert's model estimates that this depreciation gave a major boost to metals prices in 1987 and 1988 by increasing demand and reducing supply outside the United States, and that its effect continued into 1989. OECD industrial production growth is seen as the main driving force behind the price boom, but its impact in 1987 and 1988 was smaller than that of the exchange rate adjustments.

Changes in short-term interest rates and petroleum prices are seen as having been relatively unimportant factors in the metals price boom. Over the 1987-89 period, interest rates slowly increased but remained relatively low by recent standards. Thus, its negative impact on metals prices is seen to have been only minor. Petroleum prices declined in 1986, increased in 1987, declined again in 1988 but increased in 1989. The small positive impact in 1988 and 1989 reflects the delayed impact of these changes on metals prices.

Overall, Gilbert's index model produces forecast errors in the range of 11-19% of the actual level of the index. It seems likely that the large unexplained residuals resulted from the omission of supply disturbances and low stocks, because the model underestimates for both 1988 and 1989 when such factors were important.

IV. EXTENSIONS: SUPPLY DISRUPTIONS AND STOCKS

A. The Model

In order to assess the role of the supply side impact on the 1987-89 metals price boom, we develop a simple model of a representative metal market along the lines of Muth (1961) and Trivedi (1990):

$$Q_t = \alpha P_t + \eta_1 X_{1t} + u_{1t}, \tag{1}$$

$$D_t = -\beta P_t + \eta_2 X_{2t} + u_{2t}, \tag{2}$$

$$I_t = \delta (P^e_{t+1} - P_t - r_t) + \mu D_t, \tag{3}$$

$$I_t = I_{t-1} - D_t + Q_t, \tag{4}$$

where P_t is the price of the metal in period t and P^e_{t+1} is the expected price in t+1 conditional on information available in t. As in Trivedi, the Muthian supply (Q) and demand (D) models are extended to include exogenous shift variables (X_1 and X_2). However, unlike agricultural commodities dealt with by Muth and Trivedi, metals production depends on the current rather than expected next-period prices. Inventory demand (I) consists of speculative and transactions components; the speculative demand is a linear function of the expected price change minus the interest (r) cost of stock holding, while the transactions demand is a constant fraction of current demand.[2] It is assumed that inventory demand will always be met and that stocks are sufficiently large to

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[2] This could be a costly simplification. The supply-of-storage literature has explained the transactions demand for inventories in terms of convenience yield and the cost of holding inventories (storage and interest costs). Over the 1980s, the drive to cut costs led to increasing adaptation of just-in/just-out inventory management, which implies lower convenience yield from a given level of stocks than before.

prevent stock-outs.[3] The supply and demand disturbances, u_{it}'s, are assumed to be white-noise processes. All variables are expressed in logarithms of the original values. Metals prices are in real dollars; they are deflated with the US wholesale price index.

Combining (1)-(4) and solving for P_t yields:

$$P_t = \lambda \ P_{t-1} + \eta \ P^e_{t+1} - \eta \ P^e_t \ + \ w_t, \tag{5}$$

where

$$\lambda = (\delta+\mu\beta)/m,$$

$$\eta = \delta/m,$$

$$m = \delta+\alpha+\beta(1+\mu),$$

$$w_t = m^{-1} \ \{\lambda(r_t-r_{t-1})+\eta_1 X_{1t}-\eta_2[X_{2t}-\mu(X_{2t}-X_{2t-1})]$$
$$+u_{1t}-u_{2t}-\mu(u_{2t}-u_{2t-1})\}.$$

Suppose that the quadratic form:

$$\eta \ \theta^2 - (1+\eta) \ \theta + \lambda = 0, \tag{6}$$

has two real roots θ_1 and θ_2 such that $\theta_1<1$ and $\theta_2>1$. Further assume that the process defined by:

$$v_t = (1-\eta\theta_1)^{-1} \sum_{i=0}^{\infty} \ \theta_2^{-i} \ E(w_{t+i}|\Omega_t), \tag{7}$$

is a realizable stationary process, where Ω_t is the information set available in t. Then, Pesaran (1987) has shown that the unique reduced-form forward solution of (5) is given by:

$$P_t = \theta_1 \ P_{t-1} + v_t - (1/\theta_2) \ E(v_t|\Omega_{t-1}). \tag{8}$$

The conventional method of deriving estimable price equations from (8) is to assume stochastic processes generating X_1, X_2 and the interest rate. With more general forms of stochastic processes, the reduced-form price equation takes the form:

$$P_t = \theta_1 \ P_{t-1} + f\{\text{current and past values of } X_1,\ X_2,\ r_t,\ \text{etc.}\}, \tag{9}$$

where f{.} is a linear function of the relevant market fundamentals.

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[3] For versions of the model with stocks constrained to be non-negative, see Miranda and Helmberger (1988), and Deaton and Laroque (1989).

To investigate the effects of supply disruptions and low stocks, we use a combination of different approaches taken by Trivedi and by Gilbert and Palaskas. Instead of estimating a structural reduced-form price equation such as (8), Trivedi derives a "semi-structural" price equation from the inventory demand equation so that current prices are not dependent on current supply and demand. Unlike Trivedi, we impose current-period market clearing, given the level of inventories carried over from the previous period. Thus, combining (1)-(4) under the assumption that I_{t-1} is given, and solving for P_t:

$$P_t = \eta \, P^e_{t+1} - m^{-1} \, (I_{t-1} + y_t), \tag{10}$$

where $$y_t = \lambda r_t + \eta_1 X_{1t} - \eta_2 (1+\mu) X_{2t} + u_{1t} - (1+\mu) u_{2t}.$$

Taking the conditional expectation of P_{t+1} in (8) given Ω_t, we get:

$$P^e_{t+1} = \theta_1 \, P_t + (1-1/\theta_2) \, E(v_{t+1}|\Omega_t). \tag{11}$$

The expression in (11) is used to rewrite (10), to get:

$$P_t = n^{-1} \, \{I_{t-1} + y_t + [\delta(1-\theta_2)/\theta_2] \, E(v_{t+1}|\Omega_t)\}, \tag{12}$$

where $$n = \delta\theta_1 - m.$$

Equation (12) is a semi-structural price equation more general than that of Trivedi's in that the current market price is determined by current supply and demand and expectations of future market fundamentals; and given the stocks carried over from the last period. Thus, the forecast errors of the stock behavior equation in (4) do not cumulate, i.e., the model assumes that the market observes _ex post_ the errors in forecasting stock behavior and makes decisions on the basis of that information. Although this makes the model not fully dynamic, it has the advantage of better explaining historical data than (8) because stock behavior has proven to be notoriously unstable and stock carryovers are a part of the information set in determining the current market price.

The price equation (12) states that the current price is determined by stock carryovers, current and expected realizations of market fundamentals, and supply and demand disturbances. As in (9), the estimable version of (12) would include the current and lagged observations of structural variables and disturbances. To measure the effects of supply disruptions, we first estimate the expected and unexpected components of supply movements. Following Gilbert and Palaskas, we postulate that capacity expansions and hence production increases respond to prices with some lags. Then, the first difference of production may be expressed as:

$$DQ_t = f(DP_t, \, MADP_{t-m}, \, MADP_{t-n}), \tag{13}$$

where D is the first-difference operator, $MADP_t$ is the three-year moving average of price changes, and m and n are the medium- and long-term investment gestation lags, respectively. Residuals from regression of (13) are used as a proxy for supply disturbances (Q^*) in estimation of (12).[4]

On the demand side, the structural variables and disturbances are included in the price equation directly. The demand-shift variable is represented by the index of OECD industrial production (IP). The error term in the econometric estimation model of (12) consists of the current-period demand disturbances as well as errors of observation.

Finally, the semi-structural price equation to be estimated, expressed in the first-difference form, may be written as:

$$DP_t = f(DIP_t, DQ^*_t, DI_{t-1}, DEX, Dr), \tag{14}$$

where f(.) is a linear function and DEX represents exchange rate changes. Exchange rate changes have been recognized as an important supply and demand shift factor at the national level. Problems relating to their inclusion in a global aggregate model as in (14) are discussed in Gilbert (1989).

B. Results

The results of estimating (14) are reported in Table 4. Related estimates of the supply equation in (13) are shown in an annex to this paper. First note in Table 4 that the Durbin-Watson statistics indicate no serial correlation problem in the estimates, except for zinc. Inclusion of the lagged dependent variable in the zinc equation, as would be the case with the reduced-form price equation in (8), does not improve the Durbin-Watson statistic appreciably. This result suggests that the presence of lagged prices as an explanatory variable implied by the rational expectations solution of the model is not supported by the data.[5]

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[4] Since DP_t is an endogenous variable, it may be necessary to use a simultaneous equation technique to estimate (13).

[5] Estimates with the lagged price variable, either in first differences or in levels, show that its coefficient is statistically insignificant or, when it is significant, the coefficient of IP is not significant. Thus, the results indicate that the lagged price variable probably should not appear in the price equation.

Table 4: Estimates of Metals Price Equation

(Dependent Variable: DP_t)

Indep. Variables	Copper	Aluminum	Tin	Nickel	Lead	Zinc
Intercept	-0.131	-0.148	-0.059	-0.057	-0.118	-0.175
	(3.56)	(4.16)	(1.20)	(1.07)	(3.01)	(4.46)
DIP_t	3.703	3.846	1.308	1.929	2.795	5.450
	(5.00)	(5.14)	(1.30)	(1.75)	(3.29)	(6.17)
DQ^*_t	-1.390	-2.817	-0.913	-0.925	-2.934	-4.408
	(1.47)	(4.59)	(1.20)	(1.66)	(2.29)	(5.22)
DI_{t-1}	-0.294	-0.581	-0.378	-0.279	-0.787	-0.683
	(3.42)	(4.36)	(1.58)	(2.41)	(4.19)	(4.65)
MADEX	-0.710	-0.589	-0.269[a]	-1.542[a]	-1.238	-0.496[a]
	(1.62)	(1.39)	(0.52)	(2.79)	(2.68)	(1.44)
DTBR	-0.008	-0.013	0.024	-0.037	0.004	-0.020
	(0.43)	(0.74)	(0.90)	(1.34)	(0.23)	(1.04)
R^2	0.746	0.765	0.306	0.425	0.762	0.812
D-W	2.160	1.667	2.185	2.329	2.295	1.181
s.e.	0.131	0.116	0.172	0.186	0.133	0.115
s.d.(DP_t)	0.233	0.214	0.186	0.221	0.245	0.239

[a] one-year lagged values are used instead of moving averages.
Notes: Absolute values of t-ratios are in parentheses.
MADEX: Two-year moving average of the logarithmic rate of change of the GDP-weighted exchange rate index of G-7 countries' currencies per US dollar.
DTBR: Change in the three-month US Treasury bill rate.
Source: International Economics Department, World Bank.

Overall, the goodness-of-fit statistics are exceptionally good compared with earlier estimates of similar equations. R^2 values have been usually in the range of 0.4-0.6 in previous estimates of first-difference price equations, compared with 0.75-0.81 here except for tin and nickel.[6] All of the parameter estimates have the expected signs except those on the interest rate (represented by the three-month US Treasury bill rate (TBR)) for tin and lead. Generally, the estimated coefficients for DTBR are small and insignificant, probably because the interest rate does not capture forward-looking inventory behavior well. This makes sense because the interest cost of holding stocks is probably not a major consideration in speculative decisions.

Exchange rate changes appear to have been a significant factor in determining metals prices, particularly for nickel and lead. Their impact is less than immediate, however, because of the time required to work its way through supply and demand; two-year moving averages or one-year lagged exchange rate changes explain the price movements better than current-year values. Estimates of the exchange rate impact may be understated because the data period covers the 1960s when the fixed exchange rate regime was in place.

Estimates of the demand and supply shift parameters and the intercept term are highly significant, with exceptions for tin and nickel. The intercept term shows the rate of change of constant-dollar metals prices if none of the explanatory variables change; for example, the copper price will decline by 13.1% if industrial production, stocks, exchange rates and interest rates remain constant and copper production changes as anticipated. Thus, in a long-term steady state when stocks, exchange rates and interest rates remain constant and industrial production grows at a constant rate of, say, 3% annually, and there are no surprises in the rate of copper production growth, the real copper price would decline by about 2% annually (-0.131+3.703x0.03=-0.0199). Note that the surprise-free growth rate of copper production is estimated at 2.8% (see annex).[7] Thus, as shown in Table 5, the growth rate of industrial production should exceed that of copper production by about 0.7% in order to maintain a constant real price of copper. The differentials shown in Table 5 indicate the degree of demand response to industrial production growth over the estimation period, and could change as this relationship changes over time.

Supply innovations and stock changes have a strong impact on prices, particularly for zinc, aluminum and lead. Greater

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[6] Note that both tin and nickel prices have been extremely volatile in recent years, because, respectively, of the collapse of the International Tin Council and the instability of USSR exports, among other reasons.

[7] During the 1963-89 period, OECD industrial production grew at 3.8% and the real copper price increased by 0.8% annually, which is what the equation predicts.

Table 5: Long-Term Relationship Between Metals Prices and Quantities

	Copper	Aluminum	Tin	Nickel	Lead	Zinc
IP Growth Rate[a]	3.54	3.85	4.51	2.95	4.22	3.21
Metals Supply Growth Rate	2.80	4.80	0.75	2.79	2.49	2.59
Differential	0.74	-0.95	3.76	-0.16	1.73	0.62

[a] OECD industrial production growth rates are the rates necessary to maintain constant real prices of the metals under the surprise-free metals production growth rates shown in the second row.

Source: International Economics Department, World Bank.

sensitivity of prices to supply disruptions could be an indication of a smaller elasticity of substitution between the metal in question and other inputs. It has not, however, been shown that aluminum, lead and zinc have a smaller price elasticity of demand than copper, tin and nickel.

We now turn to analyzing the 1987-89 metals price boom using the estimated price equations. In order to decompose the actual price changes into those caused by different market fundamentals, the 1987-89 period is forecast under the assumption that various subsets of the explanatory variables did not change, by setting them equal to zero. The results of such computation are shown in Table 6. If none of the market fundamentals changed, then prices would have declined by the amount indicated by the intercepts (shown under Exp. DQ_t). The differences between actual price changes and the intercepts are, therefore, the total price changes that need to be explained.

As expected, the largest and most consistent contributor to the 1987-89 price increase was the increase in OECD industrial production. However, the price-boosting effect of higher industrial production was roughly equivalent in absolute terms to the price-depressing effect of the expected increases in metals production (Exp. DQ_t). So, in a sense, the price increases resulted mostly from changes in the market fundamentals that are beyond the realm of normal supply and demand developments, and thus are basically transitory in nature.

Table 6: Accounting for the 1987-89 Price Boom

(1987-89 average percent change)

Fundamentals	Copper	Aluminum	Tin	Nickel	Lead	Zinc
DIP_t	15.6	16.2	5.5	8.1	11.7	22.9
DQ^*_t	1.7	4.5	-2.4	2.1	0.4	7.7
DI_{t-1}	6.4	8.0	4.4	4.1	2.4	3.6
MADEX	5.8	4.9	3.7	21.3	10.2	6.8
DTBR	-0.6	-0.9	1.7	-2.7	0.3	-1.4
Unexplained	4.9	-5.5	0.1	10.2	-0.1	0.4
Total above	33.7	27.1	13.0	43.0	24.9	40.0
Exp. DQ_t	-13.1	-14.8	-5.9	-5.7	-11.8	-17.5
Actual DP_t	20.6	12.3	7.1	37.3	13.1	22.5

Notes: The numbers shown in the first five rows are the estimated percentage price changes that resulted from changes in each market fundamental. "Unexplained" is the percentage change unaccounted for by market fundamentals. Price changes that are explained by expected changes in supplies are shown under "Exp. DQ_t".

Source: International Economics Department, World Bank.

In particular, the supply disruptions alluded to earlier and the low level of beginning stocks played major roles in the price run-up. Interestingly, the impact of low stocks is shown to be relatively large and positive. However, the supply disturbances had a relatively small though significantly positive impact on price increases except for tin, for which production increased sharply in the latter part of the period.

The smallness of the estimated contribution of supply innovations comes as a surprise in view of the many publicized incidence of supply disruptions driving up prices. One possible explanation for this may be that supply disruptions often turn out to be not as serious as initially reported and usually do not visibly affect the ex-post world production figures. This aspect of the impact of supply disruptions will not be captured by the supply innovation variable, but rather will be relegated to the unexplained residual.

Exchange rate changes had a large positive impact on metals prices, but that of interest rate changes were mixed, small and insignificant for most metals. This result is consistent with that of Gilbert (1986). The smaller the US share of world trade, the larger the impact of exchange rate changes on metals prices. It is seen from Table 6 that nickel, lead and possibly zinc experienced a larger exchange rate impact than the other metals. The US shares of these three metals in world trade are not small, but most of it consists of US imports from Canada, which probably did not significantly affect prices in the rest-of-the-world trade in these metals.

Incorporation of the supply side factors substantially reduces the unexplained component and the bulk of the 1987-89 price boom can be accounted for by changes in market fundamentals. However, the unexplained residual is still considerable. It is particularly large for nickel, which experienced the wildest price upswings during the period. Thus, the nickel price episode certainly deserves an investigation of whether excessive speculation or price bubble was an important contributing factor. Aluminum and copper also show sizable unexplained components. Year to year the unexplained component was also significant for tin, lead, and zinc (see Table 7). This raises the question of whether bubbles were present in these prices as well. One cannot rule out the possibility of bubbles forming and bursting several times for these metals, if not being sustained over an extended period as presumably could have been the case for nickel. A particularly illuminating example is the case of copper that on several occasions during the boom period had sharp rallies on the news of supply disruptions or reduced exchange stocks and subsequent declines when stocks started to increase.

To see how the various market fundamentals affected metals prices over time, Table 7 presents the average percentage contributions by year, where the averages are simple arithmetic averages over the metals. OECD industrial production growth (DIP_t) was a consistently important positive contributor to the price boom, more so in 1988 than in the other two years. This is explained by higher OECD industrial production growth in 1988 (5.7%) than in 1987 and 1989 (3.1% and 3.8%, respectively). Also, supply disruptions and low stocks figured more importantly in 1988 than in 1987 and 1989. Stocks (DI_{t-1}) at the beginning of 1988 were lower than in the other two years for aluminum, copper, and lead; they were lowest at the beginning of 1989 for nickel and tin, while for zinc there was little change during 1988 (see Table 1). It is difficult to relate the estimated effects of supply disruptions to actual incidents. It is widely believed, however, that major disruptions in nickel, aluminum, lead and zinc, and copper were responsible for steep price increases in 1988.

Table 7: The Contribution of Market Fundamentals over the 1987-89 Metals Price Boom

(average percent change)

Funda-mentals	1987	1988	1989
DIP_t	9.9	18.0	12.1
DQ^*_t	1.6	4.0	1.3
DI_{t-1}	4.5	8.2	1.6
MADEX	18.2	7.8	0.4
DTBR	0.1	-0.7	-1.2
Unexplained	-4.5	11.3	-1.9
Total above	29.8	48.6	12.3

Source: International Economics Department, World Bank.

The impact of exchange rate changes (MADEX) closely match the movement of the US dollar vis-a-vis other major currencies -- i.e., depreciation up to about mid-1988 and then gradual appreciation. Thus, the lagged impact on metals prices almost vanishes by the middle of 1989. The US dollar depreciation in 1986-87 apparently was the dominant cause of the metals price increase in 1987. It still had a fairly strong impact in 1988. This result broadly agrees with that of Gilbert (1986). As expected, increases in US interest rates (DTBR) from 1988 are seen to have had negative impact on metals prices. Their importance, however, has been marginal.

If excessive speculation or a price bubble was a factor in the 1987-89 metals price boom, it was probably most concentrated in 1988 --as seen by the unexplained component in that year. It is interesting to note that the time of a likely price bubble was also the period of most supply disturbances and low stocks. This would suggest that sudden changes in certain market fundamentals could trigger the onset of bubbles. This and other aspects of the unexplained component of metals price movements will be the subject of future research.

V. CONCLUSIONS

The 1987-89 metals price boom is unique in that it has been sustained for more than three years -- the longest in the post-war period -- and still continues for copper, nickel, lead and zinc. This paper examines the causes of the boom from the point of view of market fundamentals. Because of the apparent importance of supply disturbances and low stocks, the reduced-form price equation specification was extended to incorporate supply-side variables. The resulting estimates exhibit superior fit and greater explanatory power than, for example, those of Gilbert's (1986) model. The estimates of the model and simulations of the boom period with the model suggest the following observations:

(a) The growth of OECD industrial production was the most consistently important factor in the higher metals prices. This positive influence was largely offset by anticipated increases in metals production. Thus, in a sense the metals price boom resulted mostly from changes in other market fundamentals -- namely, supply disruptions, low stocks, and US dollar depreciation -- factors which are transitory in nature. The boom will cease, as it already has for aluminum and tin, once these transitory factors disappear.

(b) US dollar depreciation was the dominant contributor to the metals price increase during the earlier part of the boom and particularly for nickel, lead and zinc. Changes in US interest rates were found to have been relatively unimportant.

(c) Supply disturbances and low stocks had significantly positive impacts on the price increases, particularly in 1988. Low stocks have been a more important and more consistent cause than supply disruptions. The modest contribution of supply shocks is surprising in view of the publicity given to them.

(d) Although market fundamentals as specified here explain most of the price boom -- much more so than in earlier studies -- the unexplained component is still considerable, suggesting that excessive speculation or bubbles exacerbated the price increases. The presence of bubbles was most likely for nickel in 1988. Also, bubbles could have been closely associated with supply disruptions.

ANNEX

A linear form of the metals supply equation in equation (13) was estimated, i.e.,

$$DQ_t = \alpha_0 + \alpha_1 DP_t + \alpha_2 MADP_{t-m} + \alpha_3 MADP_{t-n}, \tag{14}$$

where m=2 or 3, and n=5 or 6, depending on estimation results. Results of estimation are shown in Annex Table 1.

The intercept term measures the surprise-free production growth rate; estimates of this growth rate are remarkably similar for copper, nickel, lead and zinc, while aluminum and tin represent the two extremes. The short-term price elasticity of supply is measured by α_1, for which the estimates are reasonably close together, except for tin. The lagged response of capacity to prices is not obvious from the estimates for most metals; for tin and zinc, the lagged moving average prices are dropped from the equation because of highly insignificant estimates often with wrong signs. The goodness-of-fit statistics are generally poor; however, there is no strong indication that the supply innovations are serially correlated.

Annex Table 1: Estimates of Supply Equation

Parameters	Copper	Aluminum	Tin	Nickel	Lead	Zinc
α_0	0.028	0.048	0.008	0.028	0.025	0.026
	(4.90)	(4.59)	(0.81)	(1.76)	(4.86)	(3.54)
α_1	0.116	0.117	0.032	0.133	0.109	0.085
	(4.54)	(2.20)	(0.62)	(1.57)	(4.98)	(2.74)
α_2	0.094	0.007		0.021	0.091	
	(1.84)	(0.04)		(0.08)	(2.36)	
α_3	0.040	0.0004		0.059	0.045	
	(0.83)	(0.002)		(0.19)	(1.14)	
R^2	0.476	0.195	0.014	0.109	0.534	0.224
D-W	2.482	1.170	2.129	2.327	1.943	1.946
s.e.	0.030	0.053	0.049	0.082	0.026	0.038

Notes: m=2 and n=5 for nickel and copper; and m=3 and n=6 for aluminum and lead.
Source: International Economics Department, World Bank.

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